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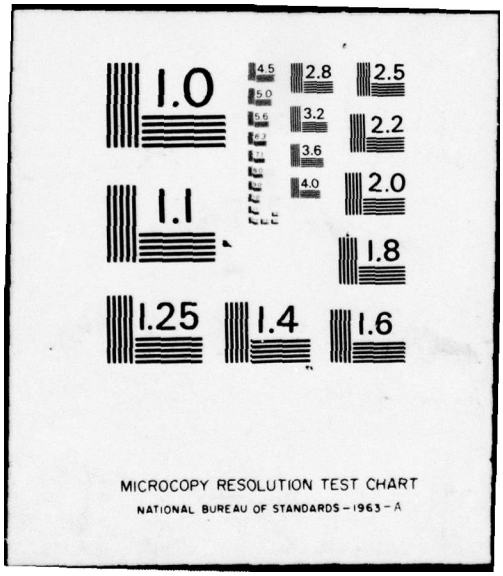
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MODIFICATION OF THE AN/TRC-97 TROPOSCATTER RADIO TERMINAL TO PROVIDE TRI-TAC COMPATIBILITY

OCTOBER 1976

Prepared for

DEPUTY FOR CONTROL AND COMMUNICATIONS SYSTEMS
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
Hanscom Air Force Base, Bedford, Massachusetts

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REVIEW AND APPROVAL

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In response to HQ USAF direction, a study was conducted to determine an appropriate modification to the AN/TRC-97 to provide a digital trunking capability and to complement the new TRI-TAC AN/TRC-170 tropo terminals. This report is a summary of the study results which were presented to HQ USAF on 18 June 1976. The modification is described and the proposed "digital AN/TRC-97" is compared

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20. Abstract (continued)

to a AN/TRC-170 on technical and life cycle cost bases. A recommended implementation plan and program schedule also are presented.

ACKNOWLEDGMENT

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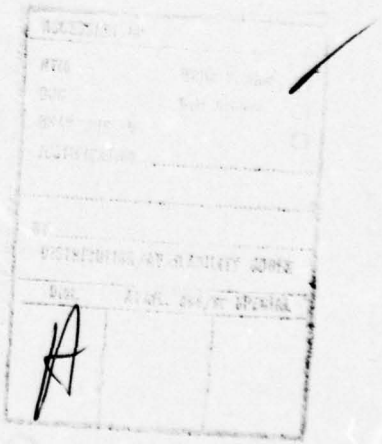
This study was completed in time to meet a very short suspense date only through the efforts of several personnel. P. Sharkey, of ESD, coordinated the effort to obtain necessary AN/TRC-97 logistics support and operational utilization data. Lt. Col. D. Noones, also of ESD, provided several helpful suggestions relative to program implementation. Of the contributing MITRE personnel, E. Cormier performed the digital AN/TRC-97 configuration analysis and F. Parsons participated in the cost analysis. The performance and technical comparisons were established by D. Erwin, S. Wenglin and J. Wick.



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1.0 SUMMARY

In response to CSAF direction (1, 2), a study has been conducted to determine how the AN/TRC-97 troposcatter radio terminal can be modified to provide a digital capability. The "digital AN/TRC-97" is to complement and be RF compatible with the future TRI-TAC AN/TRC-170 digital tropo terminals. Even though the study was conducted under a tight schedule constraint, it is felt that several firm conclusions have resulted.

Application of constraints outlined in Reference 2 results in a terminal configuration very similar to the small AN/TRC-170(V)(3). The modification is extensive and red/black interf[illegible] are introduced into the AN/TRC-97 shelter. The AN/TRC-97 equipment to be retained consists of the shelter, RF equipment and antenna group. The shelter and RF equipment have poor reliability histories and refurbishment is considered as an essential part of the digital modification program.

There will be a strong dependence on AN/TRC-170 program developed technology and hardware. The modification program is also dependent on availability of TRI-TAC multiplexing and encryption equipment. The earliest AN/TRC-97 modification production contract award date is estimated as late CY 1980. The average age of the existing USAF inventory of AN/TRC-97 radios would be 13 years at that time.

The AN/TRC-97 modification described herein is considered to be the minimum essential consistent with the given constraints (2). Several potential options and risk areas exist which could increase the complexity and cost considerably above that of the minimum

modification. Even the minimum modification, however, does not result in a significant percentage cost reduction relative to procurement of new AN/TRC-170(V)(3) terminals. Based on 250 units, 10 year life cycle cost for the digital AN/TRC-97, in constant FY 76 dollars, is estimated at $218.5 M as opposed to $264.4 M for the AN/TRC-170(V)(3). If useful life were also considered (estimated as 10 years for the digital AN/TRC-97 and 20 for the AN/TRC-170), it appears that a digital AN/TRC-97 would be more expensive than a AN/TRC-170(V)(3) on a present value cost basis. This is for a minimum modification which does not include many of the features of the new design AN/TRC-170 family.

2.0 BACKGROUND

2.1 The Present AN/TRC-97

The basic AN/TRC-97 radio system was developed by the Marine Corps during the early-mid 1960's. The first operational application was in South East Asia in 1966. Since then the AN/TRC-97 has been a primary means for providing inter-unit multichannel trunking for USMC and USAF tactical forces. Most of the current USAF inventory of 298 AN/TRC-97 series terminals are AN/TRC-97A models which have a 24-channel capability as opposed to the basic 12-channel AN/TRC-97. The remainder of the USAF inventory consists of "D" models which differ from "A" models primarily in shelter modifications. The average age of the current USAF inventory of AN/TRC-97 series terminals is 9.6 years.

The AN/TRC-97 series radios are all housed in S-308 series shelters (modified S-318 series) and provide a nominal one kilowatt output power with dual space diversity reception for tropospheric forward scatter communication. For line-of-sight operation, the high power amplifier can be bypassed and the one watt output of the intermediate power amplifier (TWT) fed directly to the antenna. Operating frequencies are selected from 1,200 available "channels" in the 4.4 to 5.0 GHz range spaced in 500 kHz increments.

All radio terminals include either 12-channel or 24-channel frequency division multiplex (FDM) equipment (GCC-5 or GCC-6) and employ frequency modulation (FM). Radio terminal capabilities include stand-alone operation (analog voice channel two or four wire interface at radio shelter), multiplexed baseband repeater operation and insert/drop operation. Up to 16 channels of 75 baud teletype (TTY)

may be interfaced at the shelter wall and multiplexed into a single voice channel slot for radio transmission. Useful range of AN/TRC-97 links with standard eight foot parabolic reflectors is typically 50 to 80 miles. (Path loss, a function of path geometry and local meteorological conditions, is subject to wide variation. From this follows the wide variation in past and present definitions of useful range of the AN/TRC-97.) Some AN/TRC-97F series radios have been procured for sale to Iran. Useful range is increased by providing 15' parabolic reflectors, at the expense of transport weight and setup time.

2.2 Previous Modification Proposals

Numerous minor and major modifications to the AN/TRC-97 system have been considered over the years. Many have been concerned with increased range and/or channel capacity. Such proposals typically included various options such as larger antennas, expansion to triple or quad diversity operation, increased transmitter power and lower noise receivers. With the exception of the latter, these proposed modifications tended to compromise the tactical nature of the basic AN/TRC-97.

Other proposed modifications were in response to operational shortcomings: the standard 8' antenna system is not stable even under moderate wind conditions; the radio terminal operates only on 400 Hz prime power while 50/60 Hz prime power is often readily available; the AN/TRC-97 is not RF compatible with the Army AN/TRC-112 tactical tropo terminal; and the analog FDM/FM transmission does not permit the application of trunk encryption techniques.

Currently there are four AN/TRC-97 modifications in various stages of development. The Air Force has procured AN/TRC-97F

and AN/TRC-97G antenna systems for field test and evaluation. (The "G" model antennas are 6' reflectors with masts extendable to 102' high, primarily for line-of-sight application.) Also, AFLC has awarded a production contract for high wind modification kits for all 298 AN/TRC-97 terminals in the USAF inventory. Finally, the USMC is in the process of modifying AN/TRC-97 radios, to be designated AN/GRC-201, such that they will be compatible with the Army AN/TRC-112. The objective appears to be to provide an interim secure digital trunking capability pending availability of the new AN/TRC-170 series radio terminals. The modification includes: conversion to binary FM; lower noise receivers (parametric amplifiers); predetection diversity combining; universal power operation (50, 60, and 400 Hz); and use of Army PCM multiplex/trunk encryption equipment housed in a separate shelter.

2.3 Scope of Current AN/TRC-97 Modification Considerations

The initial direction contained in Reference 1 and the subsequent guidance provided in Reference 2 result in a rather firm definition of a reasonable modification approach. The modification is to result in a digital tropo capability which complements and is RF compatible with the new AN/TRC-170 tropo terminal. A minimum of 24 voice equivalent channels must be provided and TRI-TAC developed multiplex equipment (DGM family) are to be used. Design performance parameters are to be similar to the Type 3 AN/TRC-170 and it is to be assumed that DGM equipment will be modified to provide CVSD analog/digital conversion at standard 16 or 32 Kbps rates.

Application of the above constraints results in a configuration essentially the same as the AN/TRC-170 set three baseline configuration. Compatibility at RF and similar performance implies use of the

AN/TRC-170 developed digital tropo modem. Use of DGM equipment and the provision of a capability which complements the AN/TRC-170 implies that the baseband equipment must be essentially the same as that of the AN/TRC-170. In essence, the AN/TRC-97 RF equipment, shelter and antenna group would be retained and all FDM/FM related baseband and IF equipment would be replaced. This is viewed as an attempt to extend the useful life of the AN/TRC-97 system and to reduce or spread out future investment in AN/TRC-170 radios. The central issues appear to be the cost effectiveness and life cycle cost implications of such a complementary AN/TRC-97 modification program. Also, with the AN/TRC-170 FSD contract scheduled to be awarded in late June 1976, reasonable questions may arise as to the advisability of any substantial new investment in analog AN/TRC-97 radio terminals.

3.0 DIGITAL AN/TRC-97

In order to provide a meaningful analysis within the imposed time constraint, this study has focused on the minimum essential modification consistent with the objectives stated Paragraph 2.3. Should a modification program be pursued, other options will undoubtedly be considered in the detailed design phase.

3.1 Modification Description

All analog FDM/FM related equipment (except the TTY terminal/mux) is removed and replaced by TRI-TAC DGM equipment and a digital tropo modem. It is assumed that the DGM equipment is modified to permit stand-alone termination of digital and/or analog voice subscriber loops (loop modem cards interchangeable with CVSD cards). The receiver noise figure is improved to provide performance similar to the AN/TRC-170(V)(3). The current AN/TRC-97A shelter configuration is shown in Figure 1. Equipment which are to be removed, relocated or modified are so indicated. A possible modified configuration is shown in Figure 2, and Figure 3 presents a functional block diagram of the new baseband equipment complement.

3.1.1 Equipment Changes

The following is a summary of the changes to be made to each shelter rack.

Rack #1: The top A36 drawer (line filters) and bottom A5 drawer (post-detection combiner) are removed. Drawers A1 - A4 are moved down to allow a new group modem drawer to be installed at the top of the rack.

The identical receiver drawers, A1 and A2, are modified to improve the noise figure. For each receiver drawer, the tunnel diode

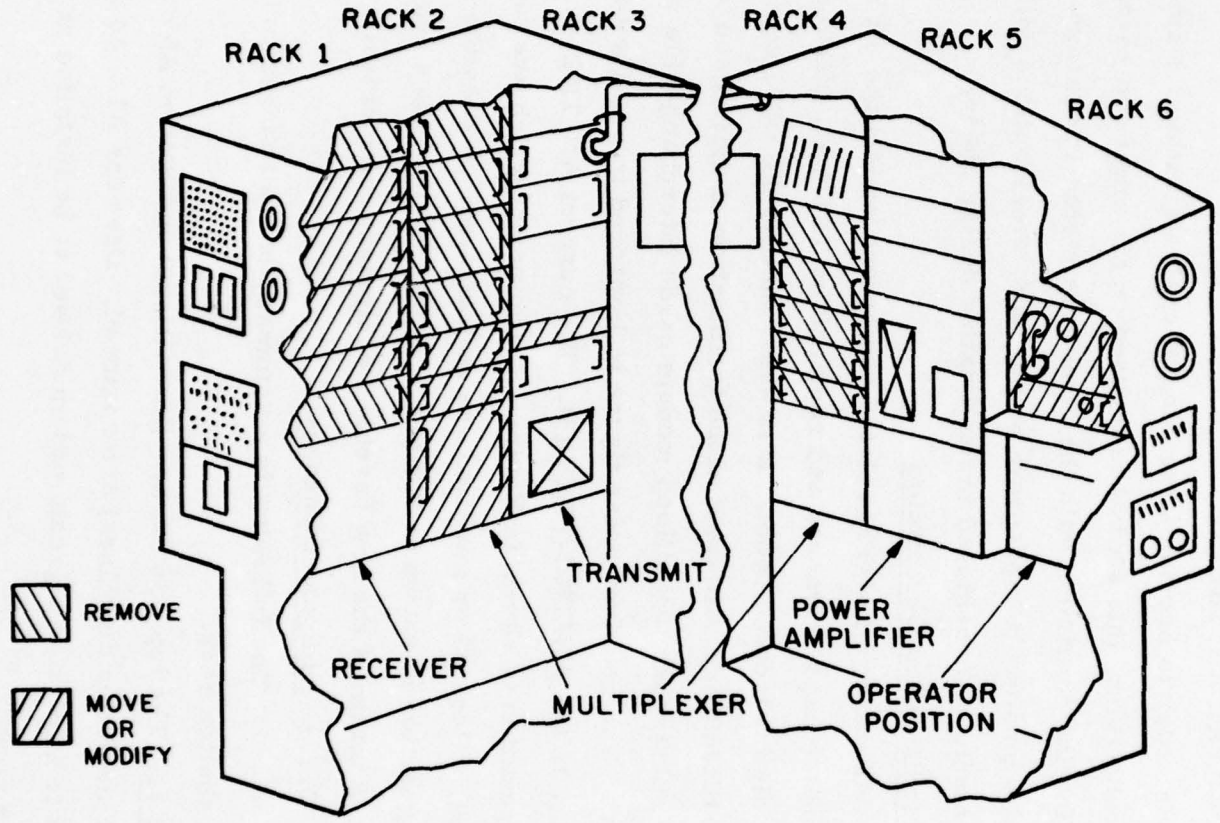

Figure 1. Cut-Away–AN/TRC-97A Shelter

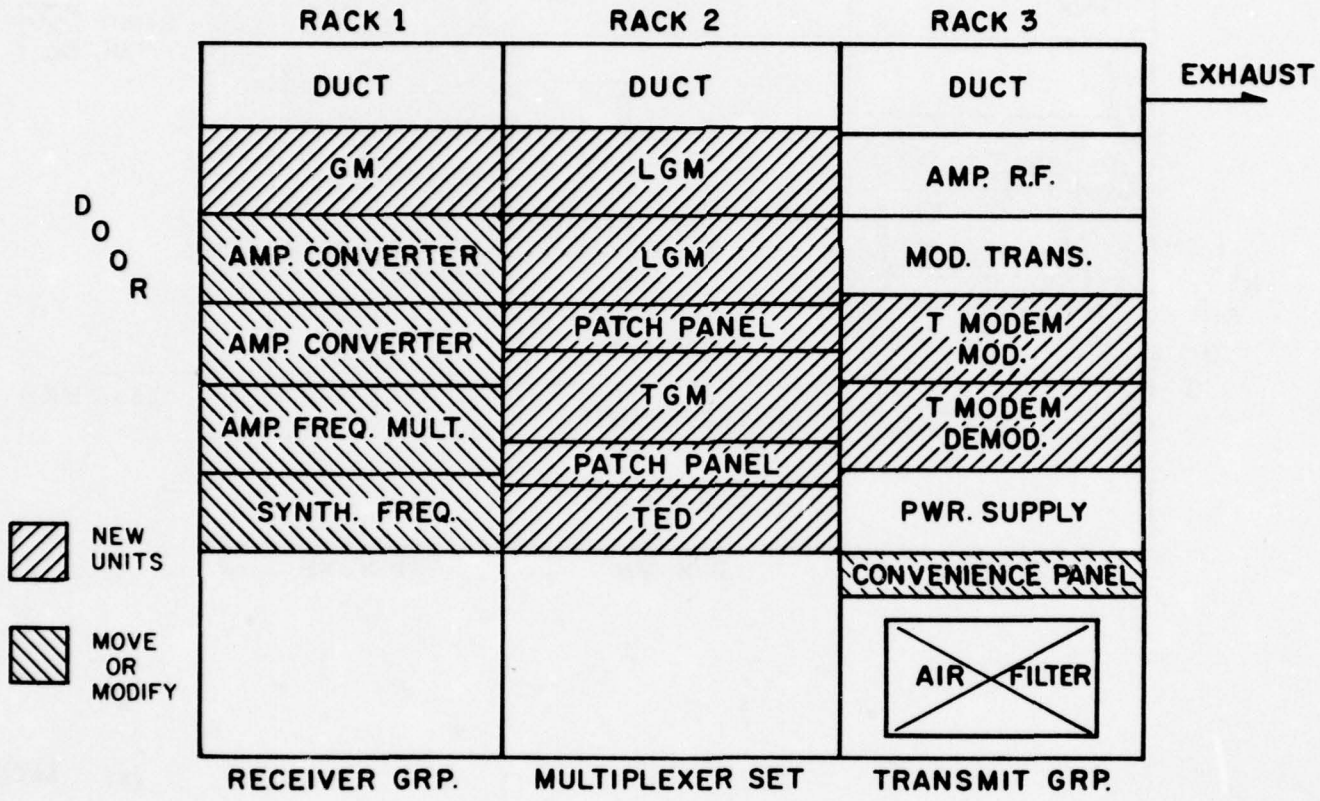

Figure 2a. Typical Configuration—Modified TRC-97A (Road Side)

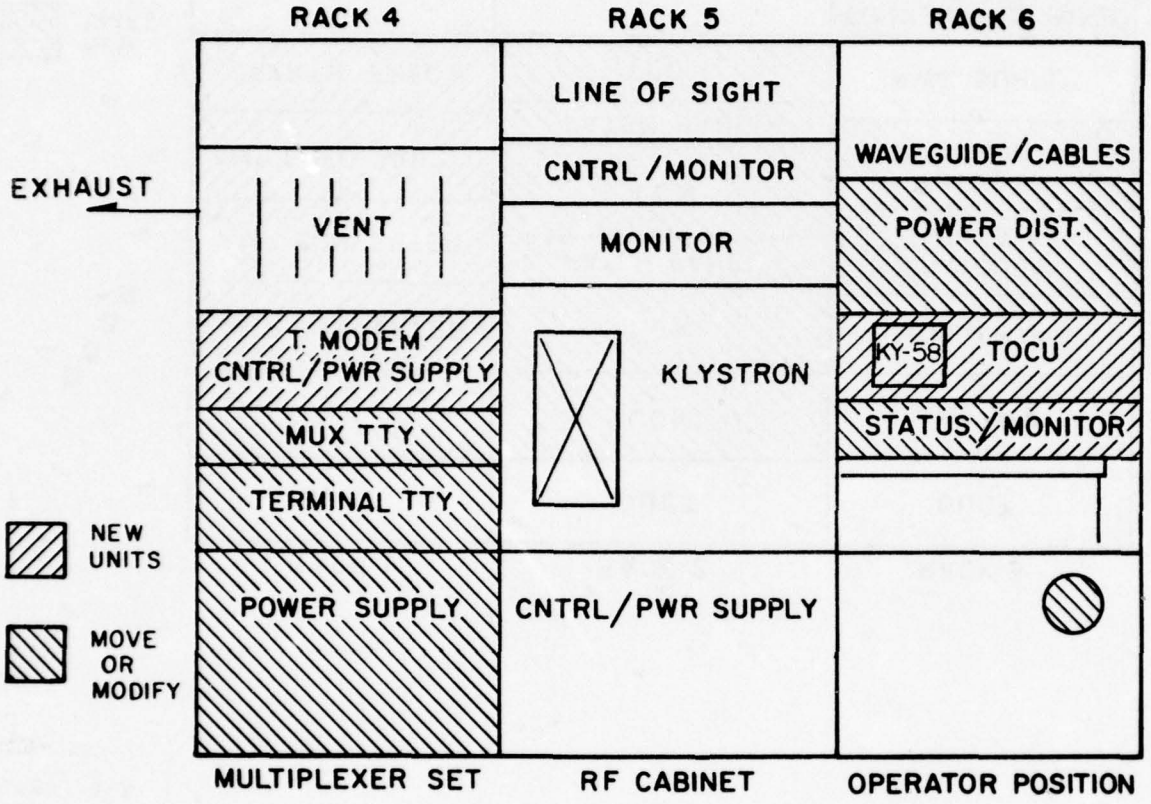

Figure 2b. Typical Configuration–Modified TRC-97A (Curbside)

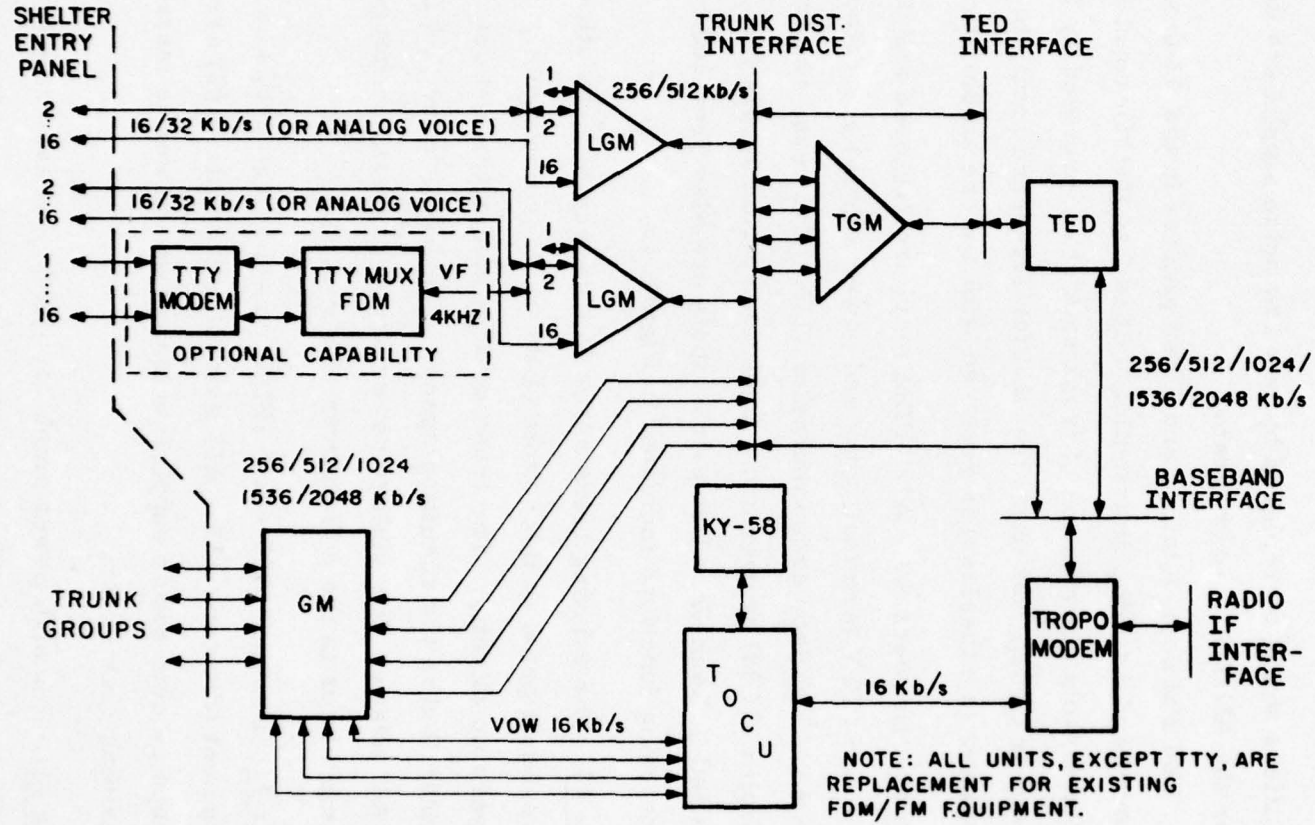

Figure 3. Digital Tropo Terminal–Functional Configuration (baseband)

amplifiers would be replaced by new low noise amplifiers developed under the AN/TRC-170 program.

The FM demodulators and IF amplifiers in the A3 drawer are removed and a timing distribution unit is installed (for count down and/or fan-out distribution of trunk rate clock provided by Tropo Modem or Group Modem). The master reference oscillator in the A4 drawer (synthesizer) is replaced with a more stable standard.

Rack #2: Drawers A7 - A12 (FDM mux) are removed and drawers A13 - A15 (TTY terminal, mux and power supply) are relocated to Rack #4. Two loop group multiplex (LGM) drawers, one trunk group multiplex (TGM) drawer and a trunk encryption device (TED) are installed in Rack #2. Two patch panels are also provided to accomplish the patching functions indicated in Figure 3.

Rack #3: The existing blank space is enlarged by relocation of the convenience panel to the bottom of the rack and by moving the top two drawers up slightly. The tropo modem modulator and demodulator are installed in the resulting space. The A16 drawer (TWT amplifier) and A21 drawer (low voltage power supply) remain unchanged. The FM modulator in the A17 drawer is removed.

Rack #4: Drawers A31 - A35 (FDM mux) are removed and the TTY equipment (drawers A13 - A15 relocated from Rack #2) are installed. A tropo modem power supply/control panel drawer is installed in the remaining rack space.

Rack #5: The high power amplifier (HPA) and associated power supply remain unchanged. The input drive attenuator may have to be changed to allow higher drive level for 7.0 MHz broadband operation. (The

AN/TRC-170 will have 3.5 MHz and 7.0 MHz bandwidth modes of operation.) In addition, some form of tuning aid may be required for broadband tuning of the HPA.

Rack #6: Operators position - the power distribution panel will require some changes in wiring and labeling. The existing status panel and orderwire handset are removed. Secure orderwire equipment (KY-58, tropo orderwire control unit and handset) and a new design status panel are installed.

3.1.2 Terminal Integration

The necessary equipment changes listed above will result in extensive changes in both signal and power distribution cabling. It is assumed that the extent and cost of these changes will be increased by the application of red/black signal isolation techniques. Also, the existing shelter signal entry panel will have to be modified to provide for additional voice subscriber loops for LGM interface and coaxial cable terminations for group modem interface. In addition to the new base-band equipment, certain, as yet undefined, test and alignment will be required. It is realized that most of the GFE equipment will have built-in test equipment (BITE) and status indicators. The radio terminal operator, however, should have the additional capability to inject known signals and to conduct various levels of loop back and link testing.

3.1.3 Unresolved Items

There are several areas which were not resolved during this initial phase. The introduction of red/black interfaces within the AN/TRC-97 shelter was addressed only to the extent that: a) an initial attempt was made to minimize certain cable runs; and b) shelter modification cost estimates reflect a COMSEC engineering effort.

If the existing 16-channel TTY capability is to be retained, an additional modification may be required. It may not be possible to employ CVSD for analog/digital conversion of the TTY multiplex output (a 16 tone composite signal). New one bit PCM A/D converters and a time division multiplexer may be required.

Even though provision was made for a more stable reference for the local oscillator (LO) synthesizer, the inherent phase jitter of the existing synthesizer may be too high for proper tropo modem operation. Depending on the chosen modem technique, a new LO synthesizer may be required.

The GFE equipment to be installed may have more stringent environmental restrictions than the equipment which is removed. A detailed thermal analysis has not been conducted to determine if the range of permissible environmental conditions has been reduced. It is possible that provision will have to be made for the addition of an environmental control unit (ECU).

The proposed modification does not include a Communication Equipment Support Element (CESE). Inclusion of a CESE would have increased the modification cost considerably and required elimination of the TTY equipment to provide the necessary space. As the CESE function (automated equipment status reporting via data ordervoice) is an important part of the TRI-TAC network control function, inclusion in a digital AN/TRC-97 may be required.

3.2 Comparison with AN/TRC-170 Set 3 Baseline

As the AN/TRC-170 source selection proceedings are still in progress, comparison with a specific set 3 configuration is not possible at this time. The AN/TRC-170 specification (3) places limits on items such as size, weight, and prime power and establishes over-

all terminal performance requirements. The offerors, within certain broad limits, have freedom in the allocation of requirements to the various subsystems. Also, it is reasonable to assume that overall performance of the future set 3 will differ from the specified performance (hopefully better) and that achieved performance will be a function of the chosen design. For these reasons, both absolute and relative performance will be a function of the chosen AN/TRC-170 design.

In the development of the AN/TRC-170 set 3 specification, a government baseline design was assumed. It is with this government baseline that the digital AN/TRC-97 is compared.

3.2.1 Performance

In addition to being somewhat artificial, as indicated above, comparison of performance with the set 3 baseline is trivial. The government performance baseline for the set 3 radio terminal was based on a radio terminal with RF performance similar to a AN/TRC-97. Performance of a digital AN/TRC-97 with the improved receiver noise figure is essentially the same as the AN/TRC-170 set 3 baseline.

The AN/TRC-170 baseline performance assumes certain tropo modem performance characteristics and channel multipath distributions. These assumptions are based on results of modem/channel simulator tests and channel measurement tests conducted at RADC. These same assumptions were used in the generation of the estimated digital AN/TRC-97 performance curves presented in Figure 4. These curves are for 99% time availability (of all hours of the year), 95% service probability, a 1×10^{-5} bit error rate and include aperture-to-

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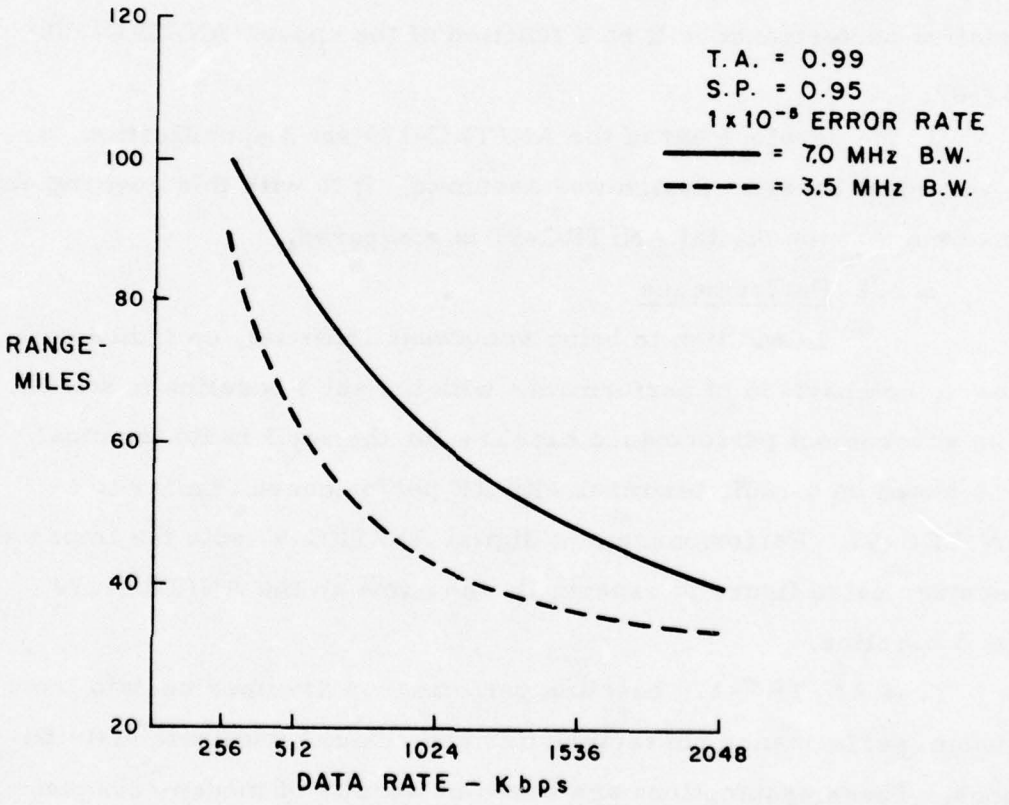

Figure 4. Digital TRC-97 Performance (Estimated)

medium coupling loss. Increased range would be available at higher error rate and/or lower time availability. It is emphasized that actual AN/TRC-170 set 3 and digital AN/TRC-97 performance will be a function of the chosen terminal and tropo modem design.

3.2.2 Terminal Design

The AN/TRC-170 set 3, as currently specified, is to incorporate several important improvements relative to the existing AN/TRC-97 design. Considerable emphasis has been placed on: improved shelter construction; suppression of antenna sidelobe response and increased antenna high wind stability; increased reliability; use of BITE and automated status monitoring (CESE); environmental conditions; and integrated logistics support. A brief summary of technical comparisons of the AN/TRC-170 set 3 and a digital AN/TRC-97 is presented in Table 1. It is not possible to quantify the overall improvement in operational utility expected to result from the AN/TRC-170 development. The design of an entirely new terminal, however, is expected to permit more flexibility in subsystem design tradeoffs than would a AN/TRC-97 modification.

With respect to those portions of the existing AN/TRC-97 which would be salvaged, data from AFLC indicates a poor reliability history. This is especially true of the HPA assembly and the basic S-308 shelter. Relatively high failure rates were also noted for the synthesizer, the local oscillator multiplier chains, the TWT amplifier assembly and the flexible waveguide. Based on two years (March 1974 - March 1976) of 66-1 system reported failures for 187 AN/TRC-97A radios, estimated MTBF for only those electrical portions of a radio terminal to be retained, is less than 800 hours. As not all failures are formally reported, this estimate is considered as optimistic. Also, it should

be noted that award of an initial digital AN/TRC-97 production contract would be during late 1980 at the earliest. This would be 14 years after the AN/TRC-97 system first became operational and possibly into the accelerated failure rate phase for many of the inventory radio terminals. It is, of course, possible to replace more of the existing AN/TRC-97 as part of the digital modification. For example, the TWT could be replaced with a solid state RF power amplifier and the existing synthesizer/multiplier chain could be replaced with a AN/TRC-170 developed synthesizer. The obvious trend is that the cost of the AN/TRC-97 modification approaches that of a AN/TRC-170 set 3 while little of the current AN/TRC-97 equipment investment is salvaged.

TABLE 1

TECHNICAL COMPARISONS

ITEM	AN/TRC-170(V)(3)	DIGITAL AN/TRC-97
Trunk Multiplexing and Stand-Alone Capability	Same	
Voice Orderwire	Same	
CESE/Data Orderwire	Yes	No
LOS Capability	> 0.5 Watt No separate LOS antennas, capable with GSQ-119/ AN/TRC-97A horns	> 1 Watt Horn antennas, 50 foot mast
Tuning	100 kHz increments	500 kHz increments
Shelter	Improved S-250 < 2500 lbs. loaded	S-308 2110 lbs. loaded
Trailer/Transit Frame	M101 Trailer < 2245 lbs. with diesel generator	Transit frame for use with M101 trailer 1925 lbs. with gas turbine generator
ECU	Yes	No (exhaust fans)
Prime Power	< 10 KW; 50/60/400 Hz	7.6 KW; 400 Hz only

TABLE 1 (Continued)

TECHNICAL COMPARISONS

ITEM	AN/TRC-170(V)(3)	DIGITAL AN/TRC-97
Generator	Not part of terminal. Trailer must accept MEP003A, 10 KW diesel	EMU-12E (PU-597/G) 20 KW, gas turbine part of terminal
Setup	1 hour, 2 men (spec.)	Approximately same
MTBF (without GFE)	1500 hours (spec.)	< 800 hours (est.)
Antennas: Maximum Sidelobes (relative to main lobe)	Dual 8' (baseline) $< \pm 15^{\circ}$, - 25 dB $\pm 15^{\circ}$ to $\pm 20^{\circ}$, - 30 dB $\pm 20^{\circ}$ to $\pm 35^{\circ}$, - 35 dB $\pm 35^{\circ}$ to $\pm 110^{\circ}$, - 40 dB $\pm 110^{\circ}$ to $\pm 180^{\circ}$, - 50 dB	Same $< \pm 14^{\circ}$, - 20 dB $\pm 14^{\circ}$ to $\pm 22^{\circ}$, - 26 dB $\pm 22^{\circ}$ to $\pm 180^{\circ}$, - 30 dB
Wind; operate	115 mph with < 1/2 of 3 dB beamwidth deflection	80 mph steady, 100 mph gusts with $< 0.6^{\circ}$ deflection with high wind kit
Wind, survive	150 mph with high wind kit	125 mph steady, 150 mph gust with high wind kit

TABLE 1 (Concluded)

TECHNICAL COMPARISONS

ITEM	AN/TRC-170(V)(3)	DIGITAL AN/TRC-97
ECCM capability	Yes	Undetermined - dependent on modem
Survivability and Vulnerability consideration	Yes	No
Useful life - years to major depot overhaul	10 years (spec.)	5 years (est.)

4.0 PROGRAM CONSIDERATIONS

In order to define a digital AN/TRC-97 configuration and estimate costs of the modification program, certain assumptions had to be made relative to the AN/TRC-170 and DGM developments. If these assumptions are not realized, there could be a significant increase in cost and/or schedule slip of the AN/TRC-97 modification program.

4.1 Relation to AN/TRC-170 Development

The most critical assumption made has been that the AN/TRC-170 program will proceed on schedule and that certain AN/TRC-170 developments will be made available as GFE to the AN/TRC-97 modification. Most important, it is assumed that two FSD tropo modems and four low noise amplifier assemblies can be available 30 months after contract award (MAC). Fully tested and proved equipment and no impact (except for cost) on the AN/TRC-170 contract is assumed. It is further assumed that all development costs are incurred under the AN/TRC-170 program and that only recurring FSD costs are applicable for these first GFE units.

Another important but less tangible AN/TRC-170 development is also expected. It is assumed that the system orientated AN/TRC-170 contractor will have solved the various interface, integration and control problems associated with the DGM equipment and the TRI-TAC network interface. In costing the AN/TRC-97 modification program, a minimum of engineering hours was allocated for consideration of system related problems.

A logical extension of the above argument might be to assume that the least expensive contractual approach is to add the AN/TRC-97 modification effort to the AN/TRC-170 contract effort. This may,

however, result in some conflict of interest as the contractor would probably favor production of the AN/TRC-170 equipment. On the other hand, if a AN/TRC-97 modification contract were awarded to a different source, and if the mix of production quantities were dependent on IOT&E test results, a healthy competitive environment might be generated.

4.2 Relation to DGM Equipment Development

The availability of DGM equipment modified to include CVSD analog/digital conversion capability is assumed to be late CY 1978 (Reference 2). It is further assumed that a current ECP, to incorporate a loop modem (LM) and loop group multiplexer (LGM) into a single drawer, will be approved. The CVSD function is assumed to be accomplished by providing CVSD cards which can be individually exchanged with LM cards. That is, the element identified as "LGM" in Figures 2 and 3 is assumed to incorporate CVSD, LM and LGM functions. This assumption is critical to the proposed digital AN/TRC-97 configuration as remaining rack space is at a minimum. Considerably more extensive redesign of the AN/TRC-97 may be required if these functions are not combined as assumed. For example, existing AN/TRC-97 drawers might have to be reconfigured and consolidated in order to make additional rack space available.

4.3 Implementation Plan

A three phase program is proposed which utilizes AN/TRC-170 developed technology and permits a production decision based on a AN/TRC-170 vs. digital AN/TRC-97 "fly off". First, a full scale development (FSD) of three digital AN/TRC-97 terminals is proposed. Two terminals would be for field testing and the third retained for tempest/reliability testing and to serve as a test bed for subsequent

engineering changes. This digital AN/TRC-97 FSD phase is strongly dependent on AN/TRC-170 developed hardware and solutions to terminal integration, control and COMSEC engineering. The schedule and cost estimates contained herein reflect this dependence.

Second, a field test and evaluation program is planned for the same time frame as the AN/TRC-170(V)(3) DTE/IOT&E test program. The primary emphasis of this phase would be to compare the operational utility of these two similar radio terminals.

Finally, a production phase is proposed where the number of AN/TRC-97 terminals to be modified is based on then current requirements and cost effectiveness relative to the AN/TRC-170(V)(3). For the cost analysis contained herein, modification of 250 radio terminals is assumed. It is also assumed that the extensive modification is performed by a contractor (rather than a depot modification) and that it is the same contractor that performed the FSD phase.

4.4 Schedule

In developing the proposed schedule shown in Figure 5, consideration was given to the current AN/TRC-170 schedule, the competitive procurement cycle, GFE availability dates, program risk and desirable decision points.

Currently, the AN/TRC-97 modification program is without funding, manpower and program direction. It has been assumed, with some degree of optimism, that these items would be available for a program start date during October 1976. The time from program start to contract award is assumed to be 21 months. This includes requirements definition, specification development and coordination (with users and industry), development of the RFP package and

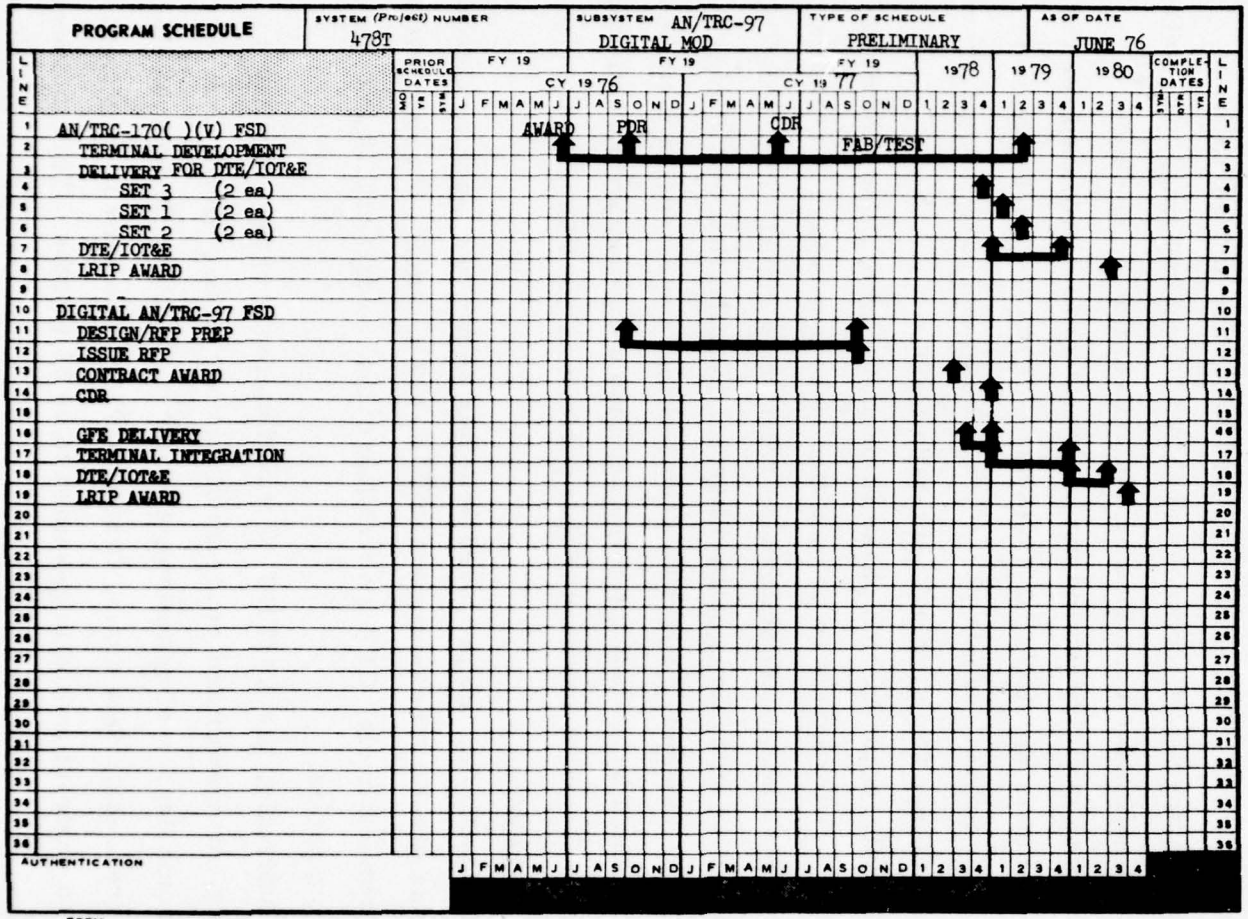

Figure 5. Program Schedule

competitive source selection. Recent experience with similar competitive procurements indicates that 21 months is a minimum expected time.

The resulting contract award date of mid CY 1978 is consistent with projected availability dates for GFE. Late CY 1978 is projected as the earliest delivery dates for full scale development (FSD) models of modified DGM equipment and the digital tropo modems (AN/TRC-170 program developed). Earlier contract award would increase risk (GFE configuration baseline would be less firm) and would probably not result in earlier digital AN/TRC-97 hardware delivery because of the GFE hardware delivery constraints.

The 18 month period from contract award to equipment delivery allows for a 6 month design phase and a 1 year fabrication phase. These are minimum times based on assumptions of early GFE delivery and a very minimum of interface/integration problems and design changes. The 6 month DTE/IOT&E test phase includes channel simulator testing, over-the-air link testing and possibly interoperability testing with a AN/TRC-170 series radio terminal. Again, especially for a troposcatter radio terminal, this period is considered the minimum essential time.

It appears that test and evaluation of a digital AN/TRC-97 could be completed in the same time frame as the AN/TRC-170 LRIP contract award, but no earlier. This would still permit a decision point relative to the production quantity mix early in the AN/TRC-170 production phase.

5.0 COST ANALYSIS

5.1 Introduction

The cost comparisons between the AN/TRC-170 and AN/TRC-97 are complex. To consider only associated hardware costs is not adequate, since the full range of cost implications to the TRI-TAC program cannot be appreciated from such a limited perspective. Hence, life cycle costs are addressed for both cases, the introduction of the new AN/TRC-170 radio and the modification of the existing AN/TRC-97 radio. Along with the technical discussions of the preceding sections, the cost sections offer a complete analysis of the program alternatives for the AN/TRC-170 and AN/TRC-97 radios.

For this exercise, many cost assumptions were made in order that the cost estimates for the AN/TRC-170 and AN/TRC-97 would be consistent with each other in context of their respective program developments. Section 5.2 presents a detailed list of the cost assumptions and ground rules which were observed for this exercise.

Section 5.3 discusses the results of the cost exercise and compares the AN/TRC-170 and AN/TRC-97 cost estimates. Included are the development (RDT&E) costs for three AN/TRC-97 full scale development (FSD) units; the incremental unit hardware costs for both the AN/TRC-170 and AN/TRC-97 radios for a production quantity of 250 units; the total investment cost for both radios for 250 units; the annual operations and support costs for both radios for 250 units; and the life cycle cost for both radios for 250 units for 10 years.

Appendix A presents the detailed cost data supporting the cost estimates presented herein.

5.2 Summary Cost Ground Rules

The following cost ground rules and assumptions were used in order to estimate the costs for the AN/TRC-170(V)(3) and modified AN/TRC-97.

5.2.1 General

- Costs are in constant FY 1976 dollars.
- The AN/TRC-170(V)(3) RDT&E will go forward in any case and these costs are considered "sunk."
- All AN/TRC-97 costs prior to program implementation are "sunk."
- Investment and operations and support costs for the AN/TRC-170(V)(3) and AN/TRC-97 are based on 250 units each.
- G&A and Fee are included in each cost category.
- The GFE costs are included.
- There will be a three-step program for the AN/TRC-97: (1) Full-scale development (FSD) of three modified sets, (2) a DTE/IOT&E using two FSD sets, (3) modification of 250 sets.
- An integration contractor will be used for the AN/TRC-97 modification. The same contractor will be used for the RDT&E and production phase.
- The schedules set forth in the technical part of this document will be followed and the GFE equipment will be delivered as required.

5.2.2 RDT&E for the AN/TRC-97

- The full scale development (FSD) will require 3 FSD sets, 2 for field testing and 1 for in-plant testing and qualification.
- The GFE will be developed on other programs.
- A single integration contractor will be used.
- The contractor will be furnished 3 AN/TRC-97 sets and he will refurbish the retained equipment.
- The contractor will maintain TRI-TAC program interfaces and will develop full data including new TOs and manuals.
- The common equipments required for the AN/TRC-170(V)(3) and AN/TRC-97 will be developed on the AN/TRC-170 program.
- The contractor training is for minimum orientation of Air Force personnel during DT&E and IOT&E. Air Force personnel costs are not included.
- The contractor will install, operate and maintain the equipment during DT&E and IOT&E.

5.2.3 Investment

- The costs are based on a learning curve for 250 units.
- The 250 AN/TRC-97s which are modified will be obtained from the existing Air Force inventory at no cost.
- The AN/TRC-97 hardware retained in the modified version will be refurbished by the contractor and not at the Air Force depot.
- GFE costs are included

- New tech orders and manuals are required for both radios.
- Training will be required for 450 organizational personnel (nine persons per section, five radios supported per section).
- CESE and ECU costs are included for the AN/TRC-170 and not for the AN/TRC-97.

5.2.4 Annual Operations and Support

- Recurring training costs for organizational personnel assumes a 30 percent annual turnover. Depot personnel turnover is assumed to be 10 percent.
- Replenishment spares for the retained AN/TRC-97 hardware is double that of new hardware since the design MTBF for new equipment is 1500 hours and the present MTBF of the AN/TRC-97 equipment to be retained is on the order of 800 hours.
- Personnel pay and allowances assumes 450 organizational personnel at the E5 level. Depot personnel are assumed to be at the E9 level. 25 are required for the AN/TRC-170 and 36 are required for the AN/TRC-97 since existing hardware on the AN/TRC-97 requires depot repair on a five-year rather than a 10-year basis.
- For consumables, it is assumed there will be on the average, 24 hour operation for three months and eight hour operation for the remaining nine months.
- The useful economic life for the modified AN/TRC-97 is 10 years and is 20 years for the AN/TRC-170.

5.3 Cost Estimates

The following are the cost estimates for modifying 250 AN/TRC-97 tropo sets into digital radios to complement the AN/TRC-170 digital sets or possibly replace the AN/TRC-170(V)(3). To place the costs in proper context, these AN/TRC-97 modification costs are compared with the estimated recurring AN/TRC-170(V)(3) costs. The AN/TRC-170 RDT&E and retained AN/TRC-97 equipment costs are assumed to be "sunk" and are not included in the following cost estimates.

The RDT&E, Investment, Operations and Support and Life Cycle Costs are shown in Sections 5.3.1 through 5.3.4 respectively. All these costs are shown in constant FY 76 dollars. The "present value" life cycle costs are also shown to indicate the comparative economic impact of these two radios with different economic lifetimes.

5.3.1 RDT&E

The RDT&E is considered "sunk" on the AN/TRC-170(V)(3) program and these costs are not included. Table 2 shows the costs to modify the AN/TRC-97, which may be on the order of 3.6 million dollars. The largest cost element is for the prototype hardware, which includes three full scale development models including the GFE costs. It may be possible to refurbish these units for later operational use but this possibility was not included in the cost estimates.

5.3.2 Investment

Table 3 shows the total investment costs for 250 AN/TRC-170(V)(3) and modified AN/TRC-97 tropo sets in constant FY 76 dollars. The total cost, including GFE equipment, is about 175 million dollars for the AN/TRC-170(V)(3) and 121 million dollars for the modified AN/TRC-97. The costs for the present equipment

TABLE 2

RDT&E

FOR MODIFIED AN/TRC-97

3 FSD UNITS

(Dollars in Thousands)

Prime Mission Equipment	
Prototype Hardware	1779
Design and Development	475
Training	5
Peculiar Support Equipment	100
DT&E and IOT&E	225
Program Management	450
Data	138
Management Reserve	476
TOTAL	3648

TABLE 3

TOTAL INVESTMENT COSTS

250 UNITS

(Dollars in Thousands)

	AN/TRC-170(V)(3)	AN/TRC-97
Prime Mission Equipment	121875.0	79825.0
Data	1218.8	1125.8
Training	708.8	492.5
Initial Spares	24375.0	15965.0
Peculiar Support Equipment	12187.5	7982.5
Common Support Equipment	3656.3	2394.8
First Destination Transportation	1377.2	1829.0
Operational Activation	3046.9	2814.4
Production Engineering Planning	3046.9	3991.3
Program Management	3046.9	3991.3
Inventory Support Management	609.4	399.1
TOTAL	175148.7	120810.7

in the AN/TRC-97 which is retained in the modified version are not included, but the refurbishment cost of this equipment, which will be over 10 years old when the radios are modified, is included.

5.3.3 Operations and Support

Table 4 shows the annual operations and support costs for 250 AN/TRC-170(V)(3) and modified AN/TRC-97 tropo sets in constant FY 76 dollars. The AN/TRC-170(V)(3) and AN/TRC-97 annual costs are about 8.9 and 9.4 million dollars, respectively.

The costs are higher for the modified AN/TRC-97 since the present AN/TRC-97 equipment which is retained in the modified version has already been in the inventory over 10 years and the depot and spares costs are expected to be greater than that of new equipment.

5.3.4 Life Cycle Costs

Table 5 indicates the total life cycle costs for the new AN/TRC-170(V)(3) and modified AN/TRC-97 tropo sets are about 265 and 218 million dollars, respectively. These costs are in constant FY 76 dollars and include RDT&E, investment for 250 sets and 10 years of full operation.

The operations and support is shown in 10 years because this is expected to be the useful economic life of the AN/TRC-97, (the present equipment retained for the modified AN/TRC-97 is already 10 years old). The useful economic life for the new AN/TRC-170(V)(3) is expected to be about 20 years. In order to indicate a more realistic economic impact of these two alternatives with different economic lifetimes, a "present value" analysis has been conducted as discussed below.

TABLE 4

ANNUAL OPERATIONS AND SUPPORT COSTS

250 UNITS

(Dollars in Thousands)

	AN/TRC-170	AN/TRC-97
Training	239.1	241.4
Replenishment Spares	1828.1	2179.9
Personnel Pay & Allowances	5227.5	5428.8
Consumables	432.0	432.0
Inventory Support Management	1218.8	1125.8
TOTAL	8945.5	9407.9

TABLE 5

LIFE CYCLE COSTS

250 UNITS
10 YEARS

(Dollars in Millions)

	AN/TRC-170	AN/TRC-97
RDT&E		3.6
Investment	175.1	120.8
O&S	89.5	94.1
TOTAL	264.4	218.5

Life cycle cost analyses which do not consider the time phase aspect of program development are adequate for general program decision purposes. However, for life cycle costs analyses, to be more reflective of the variations in program development, time phasing must be considered. For purposes of this part of the cost exercise, the period of analysis begins with the AN/TRC-97 Full Scale Development (FSD) contract award in 1978 and ends after 20 years of operation.

The time phase-in aspect of the AN/TRC-170 program is, on the whole, uncomplicated. As stated in a preceding section, the RDT&E costs are not assumed by this particular program. Production for the AN/TRC-170 begins in 1980 with 10 units. In 1981, 60 units are produced. In 1982 and 1983, 90 units are produced in each year for a total production buy of 250 AN/TRC-170 units.

Operations and Support (O&S) costs are incurred one year after production. Thus, the O&S costs for the first 10 units are incurred in 1981. O&S costs for the second 60 units are incurred in 1982, hence by 1982, 70 units are in operation and O&S costs in 1982 reflect the operation of 70 AN/TRC-170 units. By 1983, 160 units are in operation, and by 1984, all 250 units are in operation. By 1984, the complete O&S costs for 250 AN/TRC-170 radios are incurred until the end of the program in the year 2000. These O&S costs also include the 10 year refurbishment for each AN/TRC-170. The refurbishment cost per radio set is estimated to be $36 of which $15.5K is included in pay and allowances. The balance of $20.5K is apportioned as follows: material, $7K; fixed and variable overhead and G&A, $13.5K.

The present value for the AN/TRC-170 cash flow is based on a 10% discount factor (based on DoD guidance) beginning with the year 1978 through the year 2000. All costs are shown in FY 76 dollars before the discount factor is applied. The present value of the 20 year life cycle cost for the AN/TRC-170 is about $179.0 million.

The AN/TRC-97 time phase-in is somewhat more complicated than that of the AN/TRC-170. The AN/TRC-97 has already been in operation for 10 years, whereas the AN/TRC-170 is a new radio development. It is assumed the modification program for the AN/TRC-97 will extend the useful service life of the radio for only another 10 years, at which time the retained equipment modified AN/TRC-97 radios must be replaced. For cost estimating purposes, it is assumed AN/TRC-170 type equipment will be used in the replacement program.

Unlike the AN/TRC-170 program, the RDT&E costs for the AN/TRC-97 modifications must be assumed by this particular program. The total costs for the RDT&E program of $3648K will be incurred during approximately three years, with $600K estimated for 1978, $2248K in 1979, and $800K in 1980. During the last year of RDT&E, 1980, production costs for the initial 10 AN/TRC-97 units will also be incurred.

The production schedule for the AN/TRC-97 is similar to the AN/TRC-170 with 10 units produced during 1980; 60 units produced during 1981; 90 units produced in 1982 and 90 units produced in 1983.

With the exception of a five year refurbishment cycle in lieu of a ten year refurbishment cycle, the O&S costs schedule for the AN/TRC-97 is similar to the O&S schedule for the AN/TRC-170. The

refurbishment costs are assumed to be about the same as for the AN/TRC-170. Initial O&S costs for the 10 units produced in 1980 begin in 1981. In 1982, 70 AN/TRC-97 units are in operation. In 1983, 160 units are in operation and by 1984, all 250 units are in operation.

The initial 10 AN/TRC-97 units are operated for 10 years, from 1981 through 1990, and then retired. To maintain a full complement of radios, the 10 AN/TRC-97 which are retired at the end of 1990 are replaced with 10 AN/TRC-170 radios. The salvage value of the retired AN/TRC-97 radios is the GFE that can be used on the AN/TRC-170. Thus the cost of the AN/TRC-170 which replaces the AN/TRC-97 after 10 years is the cost of a new AN/TRC-170 less the GFE (and related investment) value from the retired AN/TRC-97 radios. The phase-out of AN/TRC-97 radios and the phase-in of AN/TRC-170 radios extends for four years based on the production phase-in of the modified AN/TRC-97 radios. During the transitional period, from 1990 through 1993, there will be both AN/TRC-97 and AN/TRC-170 units in operation. The total cash flow during the four year transition period reflects the gradually reduced O&S costs of the AN/TRC-97 complement and the increasing O&S costs of the AN/TRC-170 complement.

By the beginning of 1994, the entire set of AN/TRC-97 units will have been replaced by AN/TRC-170 radios which will continue in operation for 10 years until the year 2000.

The present value for the AN/TRC-97 cash flow is based on a 10% discount factor beginning with the initial cost event in 1978 through the year 2000. The present value life cycle cost for the

AN/TRC-97 is about $188.0 million.

The present value LCC for both the AN/TRC-97 and the AN/TRC-170 are presented in Tables 6 and 7 for comparison.

It might be noted that the modified AN/TRC-97 which was configured and costed in this study does not include the CESE which is part of the AN/TRC-170(V)(3). A detailed technical analysis of including the CESE into the modified AN/TRC-97 has not been attempted. However, based on the estimates for other programs and the cost estimating factors used in this study, a "ball park" estimate of the life cycle cost impact of adding the CESE has been made.

The additional 10 year cycle costs in constant FY 76 dollars for adding the CESE are estimated to be about 20 million dollars, including about $.5 million for RDT&E, $15.6 million for investment and $3.6 million for 10 years of operations and support.

TABLE 6

LIFE CYCLE COSTS

(Present Value - Thousands of Dollars)

AN/TRC-170(V)(3)

Year	Production No. of Units	Depot Overhaul No. of Units	O&S No. of Units[1]	Total Cash Flow	Present Value @ 10%
1978					
1979					
1980	10			7005.9	6074.1
1981	60		10	42393.5	33406.1
1982	90		70	65558.2	47005.2
1983	90		160	68778.6	44843.7
1984			250	8945.5	5295.7
1985			↓	↓	4812.7
1986			↓	↓	4374.3
1987			↓	↓	3980.7
1988			↓	↓	3622.9
1989			↓	↓	3291.9
1990		10	↓	9150.0	3056.1
1991		60	↓	10175.0	3093.2
1992		90	↓	10790.0	2978.0
1993		90	↓	10790.0	2708.3
1994			↓	8945.5	2039.6
1995			↓	↓	1860.7
1996			↓	↓	1690.7
1997			↓	↓	1538.6
1998			↓	↓	1395.5
1999			↓	↓	1270.3
2000			↓	↓	1154.0
					179492.3

[1] No. of Units in operation

TABLE 7

LIFE CYCLE COSTS

(Present Value - Thousands of Dollars)

MODIFIED AN/TRC-97

Year	FSD No. of Units	Production No. of Units	Depot Overhaul No. of Units	O&S No. of Units[4]	Total Cash Flow	Present Value @ 10%
1978	3				600	600
1979					2248	2144.6
1980		10[1]			5632.4	4883.3
1981		60		10	29370.8	23144.2
1982		90		70	46125.9	33072.3
1983		90		160	49512.8	32282.4
1984				250	9407.9	5569.5
1985			10[3]	|	9612.9	5171.7
1986			60	|	10637.9	5201.9
1987			90	|	11253.4	5007.8

[1] AN/TRC-97 Units

[2] AN/TRC-170 Units

[3] AN/TRC-97 Units Overhaul

[4] In 1983, 250 AN/TRC-97 units are in operation, from 1990 through 1993, AN/TRC-97 units are replaced with AN/TRC-170 units according to the production schedule phase-in program. However, there will always be 250 radio units (either AN/TRC-97s or AN/TRC-170s) in operation. The cash flow reflects the O&S cost difference between the AN/TRC-97 and AN/TRC-170.

TABLE 7 (Concluded)

Year	FSD No. of Units	Production No. of Units	Depot Overhaul No. of Units	O&S No. of Units[4]	Total Cash Flow	Present Value @ 10%
1988			90		11253.4	4557.6
1989					9407.9	3462.1
1990		10[2]			15397.8	5142.9
1991		60			45328.8	13779.9
1992		90			63187.5	17439.8
1993		90			63021.1	15818.3
1994					8945.5	2039.6
1995						1860.7
1996						1690.7
1997						1538.6
1998						1395.5
1999						1270.3
2000						1154.0
						188227.7

[1] AN/TRC-97 Units

[2] AN/TRC-170 Units

[3] AN/TRC-97 Units Overhaul

[4] In 1983, 250 AN/TRC-97 units are in operation, from 1990 through 1993, AN/TRC-97 units are replaced with AN/TRC-170 units according to the production schedule phase-in program. However, there will always be 250 radio units (either AN/TRC-97s or AN/TRC-170s) in operation. The cash flow reflects the O&S cost difference between the AN/TRC-97 and AN/TRC-170.

REFERENCES

1. HQ USAF Program Management Directive R-P 5090(2)/28010F for Combat Theater Communications Program (478T), 29 March 1976.

2. CSAF/RDP/KRC Message 072131Z, Subject: "AN/TRC-97 Modification," May 1976.

3. "Performance Specification for AN/TRC-170( )(V) Radio Terminal Set," TTB1-2203-0025A, 15 March 1976.

APPENDIX A

DETAILED COST BACKUP DATA

The following is an explanation of the cost estimates which were developed for the modified AN/TRC-97 and the AN/TRC-170(V)(3). The resulting costs are shown in Tables 2, 3, and 4 (RDT&E, Total Investment Costs, and Annual Operation and Support Costs, respectively) in Section 5.3.

RDT&E Costs

The RDT&E costs for the AN/TRC-170(V)(3) are considered "sunk" on the 170 program and are not included. The RDT&E costs for the AN/TRC-97 are those costs to modify the existing radios for the future TRI-TAC environment, and to extend their useful life.

- Prime Mission Equipment
  - Prototype Hardware

It is assumed 3 full scale development (FSD) models will be required for the development program -- 1 for in-plant development and testing, and 2 for DT&E and IOT&E testing.

The GFE costs were estimated at 150 percent of the unit hardware costs of $91K. The new and refurbished equipment costs, including integration, test, and assembly, were estimated at 200 percent of the unit hardware costs of $228.3K.

  - Design and Development

An 18 month design and development effort is required for new equipment, for modification of equipment developed under other programs, and to reconfigure and integrate the AN/TRC-97 facility. The engineering to develop and modify the Synthesizer, Low-Noise Amplifier, TOCU, Power Distribution Panel, Clock Distribution Unit,

Red and Black Panels, and the Shelter and Shelter Panels is estimated at 31 man-months. Test plans, specifications and test preparations are estimated at 24 man-months, and integration and coordination for all the equipment to be installed into the facility (including GFE equipment) is estimated to take 40 man-months for a total of 95 man-months. Assuming $60,000 per engineering man-year (including overhead and G&A and fee), the total cost is $475,000.

- Training

The contractor will operate and maintain the AN/TRC-97 during the 6 month DT&E, IOT&E period. However, the contractor will provide a one-week orientation course for the Air Force personnel who will be present during the test period. The cost of this course is estimated at $5000.

- Peculiar Support Equipment

The required peculiar support equipment (PSE) has not been defined at this time. However, based on other programs, PSE is estimated at 10 percent of the investment prime mission equipment (PME), and three sets of PSE are required. The PME per unit cost is $319,300, so the three PSE sets are estimated to total about $100,000.

- DT&E and IOT&E

There will be a 6 month test period, including the time to install and check out two full scale development model (FSD) AN/TRC-97s at the test site.

The transportation cost to the field is estimated at 1 percent of the investment PME, plus the required PSE and common support equipment (CSE) (see investment costs) or about $7200 for the two FSD units.

Test spares and materials are estimated at 5 percent of the two FSD units used for field testing, or about $59,000.

The contractors will furnish four persons for the 6 month test period at a rate of $60,000 per man-year. The contractor will install, operate and maintain the equipment during this test. Per diem is estimated at $50 per day, and contractor personnel travel pay is estimated at $2000 for the four personnel. The total contractor personnel costs are therefore about $160,000.

The total DT&E and IOT&E costs, including transportation, spares, and contractor costs total about $350,000.

- Program Management

Program management estimates a nine man-year effort over the two-year RDT&E time period at a rate of $50,000 per man-year, at a total cost of about $450,000.

- Data

It is assumed the modifications of the AN/TRC-97 are of such an extent that a complete set of data including new TOs are required. The data costs are estimated at 13 percent of the design and development and one FSD prototype cost, or about $138,000.

- Management Reserve

The RDT&E estimates are preliminary in nature and there is some uncertainty concerning the development effort required. Therefore, for budgetary purposes, a management reserve of 15 percent of the total RDT&E costs, or about $476,000, is included to cover contingencies.

Investment Costs

The investment cost estimates for the AN/TRC-170(V)(3) and

AN/TRC-97 modified are explained below. Total investment costs for the AN/TRC-170(V)(3) are estimated, and the GFE costs for both radios is included. The costs for the existing AN/TRC-97 equipment which is retained are considered "sunk" and are not included. However, the costs for refurbishing this retained equipment, including the existing shelter, is included.

- Prime Mission Equipment

Table I lists the individual equipment items included in the two radios, with the per unit costs in FY 76 dollars, assuming a quantity of 250 units. The costs are based on the present AN/TRC-170 program estimates where appropriate and on similar equipment. The GFE cost estimates were based on estimates provided by TRI-TAC for the Army DGM and NSA Tenley Programs.

The synthesizer will be retained in the modified AN/TRC-97; however, some modifications are required to replace the master oscillator with a more stable standard. The Synthesizer Modification costs are based on the materials and manpower efforts required to complete this task.

The Low Noise Amplifier cost estimates for the AN/TRC-170 and AN/TRC-97 are somewhat different even though the AN/TRC-97 low noise amplifier will be obtained as a GFE item from the AN/TRC-170 program. The cost differences arise because the low noise amplifier cannot be incorporated into the AN/TRC-97 without some integration and modification costs to the receiver drawer.

The Digital Modem cost estimates for the AN/TRC-170 and AN/TRC-97 are different because the AN/TRC-97 modem will be a stand-alone unit and will require a separate power supply drawer. On

TABLE I

UNIT HARDWARE COSTS

(Dollars in Thousands)

	AN/TRC-170(V)(3)	AN/TRC-97
Exciter	37.8	-
PA/HVPS (1 KW)	43.2	-
	81.0	-
Receiver/Synthesizer	43.2	-
Synthesizer Modification		3.0
Low Noise Amplifier	17.2	18.0
Digital Modem	60.0	63.0
Tropo Order Wire Control Unit	8.1	7.5
TOCU Patch Panel (Status/Monitor Panel)	-	8.4
Telemetry Combiner	10.8	-
CESE	12.9	-
Power Distribution	2.2	-
Power Distribution Panel Mod.	-	3.0
Clock Distribution Unit	-	7.2
Red Patch Panel	-	4.2
Black Patch Panel	-	2.6
	154.4	116.9
Shelter	6.5	-
Shelter Panel Mod. (Mat'l)	-	.6
Shelter Entry Panel Mod.	-	2.4
Trailer (M 101)	.9	-
Antenna Group (8' dish/15' tower)	74.6	-
	82.0	3.0

TABLE I (Concluded)

	AN/TRC-170(V)(3)	AN/TRC-97
GFE Items		
Loop Model	32.9	-
Trunk Group Mux	12.5	12.5
Group Modem	9.2	9.2
Data Channel Mux	3.5	-
Loop Group Mux (Incl. LM for 97)	26.4	59.3
DLED	8.0	-
TED	7.0	7.0
KY-58	3.0	3.0
ECU	4.0	-
	106.5	91.0
Refurbishment	-	40K
Integration/Test/Assembly	63.6	68.4
Total Excluding GFE	381.0	228.3
Total Including GFE	487.5	319.3

the other hand, the AN/TRC-170 modem will be used as an integral unit in the AN/TRC-170.

The Tropo Order Wire Control Unit (TOCU) cost estimates for the AN/TRC-170 and AN/TRC-97 are different because part of the AN/TRC-97 TOCU functions are performed by the TOCU Patch Panel (Status/Monitor Panel), whereas the AN/TRC-170 TOCU includes the patch panel.

The Telemetry Combiner and CESE are required in the AN/TRC-170 but not in the AN/TRC-97. The AN/TRC-97 already has a Power Distribution Unit; however, the Power Distribution Panel must be modified to fit into the new rack configuration. The power distribution panel modifications are extensive and essentially require a complete reconstruction of the unit at a cost which approximates that of a new unit.

A Clock Distribution Unit is required in the AN/TRC-97 to coordinate the synchronization functions of the other clocks in the AN/TRC-97. Separate Red and Black Patch Panels are required to provide for red/black signal isolation.

Shelter Panel Modification Materials and Shelter Entry Panel Modifications are costs associated with the reconfiguration and rewiring of racks within the AN/TRC-97 to accommodate the charges in electronics equipment.

For the GFE items, there is a Loop Modem (LM) in both the AN/TRC-170 and AN/TRC-97 radios. In the AN/TRC-170, the loop modem is a separate unit from the Loop Group Multiplexer (LGM). However, in the AN/TRC-97, the loop modem and loop group multiplexer are combined into a single unit. In addition, the CVSD function is

included by providing CVSD cards which can be exchanged with LM cards. The cost of the combined LM/LGM is expected to be less than the sum of the separate unit costs. Addition of the CVSD, however, will increase the cost. It has then been estimated that the combined LGM/LM/CVSD function for the AN/TRC-97 is equal to the sum of the AN/TRC-170 LGM and LM separate unit costs.

The AN/TRC-97 equipment which is retained, such as the exciter, PA/HVPS, and shelter, will require refurbishment. This equipment represents about 50 percent of the present total estimated cost of an unmodified AN/TRC-97 of about $245,000. The Air Force Logistics Command periodically refurbishes the existing AN/TRC-97 at depot at a cost of about $40,000 per unit, including labor and materials. About 10 percent of this effort is to disassemble the entire radio, 75 percent to refurbish and 15 percent to reassemble.

The refurbishment cost of the modified AN/TRC-97 includes the total disassembly cost of about $4000, and 50 percent of the refurbishment cost, or about $15,000. The re-assembly cost is included in Integration/Test/Assembly discussed below. The total cost for the Air Force depot refurbishment is therefore about $20,000 for the retained equipment. Since it is assumed the integration contractor will perform this effort, this estimate is doubled for contractor overhead and G&A and fee.

In-plant integration of the equipment, test, and assembly into the shelter is estimated at 15 percent of PME costs for the AN/TRC-170, or about $63,600. The cost for the AN/TRC-97 is estimated at 20 percent of the PME costs, including the existing equipment (the total cost of which is about $131,000), or about $68,400. The higher factor of 20 percent is used because of the modifications to racks required to fit the new equipment into the existing shelter.

- Data

It is assumed a complete new set of Tech Orders and Manuals is required for both radios since the AN/TRC-170 is new and the modifications to the AN/TRC-97 are extensive. The recurring reproduction costs are estimated at 1 percent of the PME costs, including the retained existing equipment in the AN/TRC-97.

- Training

For planning purposes, the Air Force estimates the 450 organizational personnel will be required to support 250 radios, based on 9 men per section, with each section supporting 5 radio sets.

The additional training for the AN/TRC-170 personnel, assuming they already have an electronics MOS, will take about three weeks, at a cost of about $525 per man per course week according to the Air Force training command. The cost of course preparation and depot personnel training is considered "sunk" since it is included in the overall AN/TRC-170 program, and these costs will not vary significantly if the AN/TRC-170(V)(3) is not procured.

The training for the AN/TRC-97 assumes the existing AN/TRC-97 personnel need some additional training for only the new equipment. This course is estimated at two weeks (at a cost of about $525 per man per course week). Contractor course preparation is estimated at $20,000. No depot training costs are included since it is assumed the course length would not vary over the present AN/TRC-97 course, and that these costs will be "sunk" by the time the modified AN/TRC-97 is procured.

- Initial Spares

Initial spares, including filling the logistics pipeline and war readiness kits, is estimated at 20 percent of the new PME costs. No initial spares are required for the retained AN/TRC-97 equipment.

- Peculiar Support Equipment

No definitive information is available concerning the required

Peculiar Support Equipment. However, based on similar programs, the costs are estimated at 10 percent of the PME.

- Common Support Equipment

Based on similar programs, the Common Support Equipment costs are estimated at 3 percent of the PME.

- First Destination Transportation

The cost to transport the AN/TRC-170 equipment from the factory to the Air Force is estimated at 1 percent of the equipment costs, including the peculiar and common support equipment.

The existing AN/TRC-97 equipment must first be shipped from the Air Force to the contractor. This is estimated at 1 percent of the present equipment costs (of about $240,000 dollar per unit). The modified AN/TRC-97 is then shipped from the contractor to the Air Force at a cost of 1 percent of the new PME, retained PME (at about $131,100), peculiar support equipment and common support equipment.

- Operational Activation

When the equipment is delivered to the field, it will have to be installed at the operational site and checkout testing will be required. This effort includes contractor material and services. The cost of this effort is estimated at 2.5 percent of the PME plus the retained AN/TRC-97 equipment.

- Production Engineering Planning

Production Engineering Planning includes the contractor efforts required to insure the timely and economic producibility of all components and the integration of the end items prior to release to production. This effort is estimated at 5 percent of the PME for the AN/TRC-97. A lower factor of 2.5 percent is used for the AN/TRC-170(V)(3) since this effort is shared for the total AN/TRC-170 family of radios.

- Program Management

Program Management costs are estimated at 5 percent of the PME costs for the AN/TRC-97 and only 2.5 percent for the AN/TRC-170 because this effort is shared for the total AN/TRC-170 family of radios.

- Inventory Support Management

An inventory supply system must be established for the new and modified items of equipment added to the Air Force logistics supply system. This effort is estimated by the Air Force Logistics Command at about .5 percent of PME.

Annual Operations and Support Costs

The Annual Operations and Support costs shown in Table 3 are for the total 250 units. The basis for the cost estimates follow:

- Training

A training course is required each year for the new personnel entering the system.

For the AN/TRC-170(V)(3) a three-week organizational personnel course is assumed costing $525 dollars per student per week. A 33 percent attrition rate per year is assumed, so about 150 organizational personnel are trained each year at a cost of $233,890.

It is estimated about 25 depot personnel on the average will be required to support the AN/TRC-170(V)(3), repairing Line Replaceable Units (LRUs) and performing the 10 year cycle depot overhaul. The training course is assumed to require four weeks at a cost of $525 dollars per student per week. Annual attrition is assumed to be only 10 percent since more civilian and career military personnel are involved. Depot training costs are therefore about $5250 per year.

The organizational training costs for the AN/TRC-97 are assumed to be the same as for the AN/TRC-170(V)(3). Because of the lower MTBF for the AN/TRC-97 and the expected five-year depot overhaul cycle, it is assumed the present level of 36 depot personnel will be required so recurring annual depot training costs are estimated at $7,560.

- Replenishment Spares

Replenishment spares for the AN/TRC-170 and new equipment on the AN/TRC-97 are estimated at 1.5 percent of the new PME. The MTBF of the present equipment retained on the AN/TRC-97 is about half that of the new equipment, so replenishment spares for this equipment is estimated at three percent of the retained equipment cost (of about $131,000).

- Personnel Pay and Allowances

There are 450 organizational personnel for both radios, 25 depot personnel for the AN/TRC-170(V)(3) and 36 depot personnel for the AN/TRC-97.

The organizational personnel are E5 and the annual pay and allowances is about $10,600, including a permanent change of station (PCS) allowance of about $1100 for the third of the personnel added to the system each year (due to average attrition).

The depot personnel are E9 with an annual pay and allowances of about $18,300 including a PCS allowance for a tenth of the personnel added each year.

- Consumables

The major consumables used for the radios is the generator fuel. The AN/TRC-170(V)(3) prime power requirement is 10 KW

and is 7.6 KW for the AN/TRC-97 since this set does not include an air conditioner. In order to estimate fuel consumption, it is assumed each radio will operate 24 hours per day for three months and eight hours per day for the remainder of the year. Each AN/TRC-170(V)(3) will therefore use 43,000 KWH per year or 10,800,000 KWH for 250 radios. Fuel is estimated at $.04 per KWH for a total annual cost of $432,000.

Although the prime power requirement for the AN/TRC-97 is less, the fuel cost is estimated to be approximately the same as the AN/TRC-170(V)(3) because of the different generators used. (The AN/TRC-170(V)(3) will use a 10 KW diesel generator and the AN/TRC-97 uses a 20 KW gas turbine with a larger fuel requirement per KWH.)

- Inventory Support Management

The Air Force must maintain an inventory support management system for the radio parts. Based on AFLC estimates, an annual recurring factor of 1 percent of total PME is used. For the AN/TRC-97, the retained as well as new PME requires inventory support.